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TECHNICAL REPORT

NATICK/TR-78-007

IDENTIFICATION OF COMPONENTS OR FRACTIONS ASSOCIATED WITH ADVERSE CHANGES IN FREEZE DRIED CHICKEN AND PORK DURING STORAGE

AD A 091798

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STSNL 75-113

June 1978

UNITED STATES ARMY
RESEARCH and DEVELOPMENT COMMAND
NATICK, MASSACHUSETTS 01760

Food Engineering Laboratory

FEL-70

NATICK/FEL

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: NATICK/TR-78/007	2. GOVT ACCESSION NO.: AD-A091 798	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): IDENTIFICATION OF COMPONENTS OR FRACTIONS ASSOCIATED WITH ADVERSE CHANGES IN FREEZE DRIED CHICKEN AND PORK DURING STORAGE.		5. TYPE OF REPORT & PERIOD COVERED: Technical rept.
		6. PERFORMING ORG. REPORT NUMBER: FEL-70
7. AUTHOR(s): A.A. Klose, W.E. Townsend, G.E. Walker		8. CONTRACT OR GRANT NUMBER(s): DA-STSNL-75-113
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Richard B. Russell Agricultural Research Center, United States Department of Agriculture, Athens, Georgia		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AH 99BB029 AF 3-12
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Natick Research & Development Command, Natick, Massachusetts 01760		12. REPORT DATE: June 1973
		13. NUMBER OF PAGES: 44
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report): UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

FOOD(S)	PRECOOKED FOODS	DETERIORATION
FREEZE DRIED FOODS	STORAGE STABILITY	STORAGE DETERIORATION
CHICKEN	STORAGE	SENSES (PHYSIOLOGY)
PORK	STABILITY	TEMPERATURE

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Reported are the procedures and results of a six-month storage stability study, the objective of which was to further define and correlate the major physical, chemical, and sensory changes which occur during the storage deterioration of precooked, diced, freeze-dried chicken, and raw and precooked sliced freeze-dried pork under very low oxygen and moisture conditions.

Physical, chemical, and sensory changes were determined in cooked diced

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20. Abstract Continued

chicken, and raw and cooked sliced pork that were freeze-dried to residual moisture levels of less than 2% and stored in sealed tin cans under nitrogen at -40, 28, 38 and 48°C for 1, 3, and 6 months.

Analysis of headspace gas confirmed the absence of oxygen and no carbon dioxide developed during storage. There were no appreciable changes in residual moisture content of any of the products during the six-month storage period. Level of glucose decreased with increasing temperature and time of storage. Lactic acid content was 50-to 100-fold that of glucose on a molal basis and experienced no detectable change over six months at temperatures up to 48°C. No appreciable change in the level of ε-amino nitrogen was apparent. Reducing substances, expressed as ascorbic acid, increased with increasing temperature and time of storage.

There were no marked changes in percent rehydration due to storage temperature and time for cooked diced chicken, raw and cooked sliced pork.

The decrease in Hunter L values (lightness) of cooked chicken, raw and cooked pork agree with the visual observations of darkening made by the panelists.

Sensory evaluation of the differences between control samples at -40°C and samples at the three experimental temperatures, by triangle tests, revealed detectable deterioration in cooked chicken at 48°C for 1 month and thereafter; and at 38°C for three months and thereafter. For raw pork, there was significant deterioration at 38 and 48°C at three months and thereafter. For cooked pork, there was significant deterioration at 1, 3, and 6 months for all three temperatures.

A corollary experiment showed that the use of polyphosphates with salt increased the water pick-up by about 8 percent and the cooked yield based on the original unsoaked weight was 13 percent higher due to the polyphosphate treatment. Also observed was a substantial increase in the ash content that could not be accounted for entirely as increases in phosphate plus salt.

PREFACE

In 1974 Project Order 3T3NL 75-113 was issued to the Animal Products Utilization and Marketing Research Laboratory, Richard B. Russell Agricultural Research Center, Agricultural Research Service, United States Department of Agriculture, Athens, Georgia for the purpose of identifying components of fractions that are associated with adverse changes during storage in freeze-dried chicken and pork. This report includes the procedures for preparation and analysis and the chemical physical and sensory changes in freeze-dried chicken and pork during high temperature, oxygen-free storage.

This effort was undertaken as part of the U.S. Air Force requirements 3-12 "Identify Components of Post Mortem Muscle which Affect Rehydrated, Stored, Freeze Dried Meat."

An addendum reports the results of a corollary experiment in which chicken breast meat was soaked in a salt/phosphate solution, then cooked and freeze-dried. The purpose of the experiment was to determine the effect of the salt phosphate treatment on rehydration.

Dr. Arthur J. Mercuri, Chief, Animal Products Utilization and Marketing Research Laboratory served as Project Leader, with Mr. A. A. Klose and Dr. W. E. Townsend, Principal Investigators, and Ms. Brenda Lyon, Technician. Dr. Maxwell C. Brockmann and Mr. Justin M. Tuomy served as Project Officers, and Dr. Larry Hinnergardt as Alternate Project Officer for the U.S. Army Natick Research and Development Command.

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INTRODUCTION

A wide variety of freeze-dried foodstuffs is available for procurement by the Armed Services, and/or civilian consumers. Complete meals can now be served using dehydrated foods only. Many of these products rehydrate quickly and, when cooked using conventional large or small scale equipment, are difficult to distinguish from fresh or frozen foods.

However, despite all of the advantages of freeze-drying (reduction in weight, inhibition of bacteria, savings in storage and transportation), and the fact that freeze-dried meat products initially possess a number of ideal quality characteristics, initial rehydration and texture are often inadequate, and deterioration may occur during subsequent storage.

Numerous publications (Regier and Tappel, 1956a;[1] Harper and Tappel, 1957;[2] Tappel et al., 1957[3] and Ballantyne et al., 1958[4]) have described the effects of freeze-drying of meat and poultry on quality and stability. Tappel et al. (1957)[5] reported that precooked freeze-dried poultry rehydrated poorly, was tougher and had a drier texture than the control meat. Similar results were reported by Bele et al. (1966)[6] in their study on the effect of freeze-drying on the quality of cooked and raw breast and thigh meat.

[1] Regier, L. W. and A. L. Tappel. Freeze-dried meat. III. Non-oxidative deterioration of freeze-dried beef. Food Res. 21: 630 (1956a).

[2] Harper, J. C. and A. L. Tappel. Freeze-drying of food products. Adv. in Food Res. 7: 220 (1957).

[3] Tappel, A. L., R. Martin, and E. Plocher. Freeze-dried meat. V. Preparation, properties, and storage stability of precooked freeze-dried meats, poultry, and seafoods. Food Technol. 11: 599 (1957).

[4] Ballantyne, R. M., C. Brynko, A. J. Ducker, and W. R. Smithies. Dehydrated cooked meat products. Food Technol. 12: 398 (1958).

[5] See footnote 3

[6] Bele, L. M., H. H. Palmer, A. A. Klose, and T. F. Irmiter. Evaluation of objective methods of measuring differences in texture of freeze-dried chicken meat. J. Food Sci. 31: 791 (1966).

According to Tuomy and Felder (1964),[7] freeze-dried cooked sliced pork was considered for inclusion in military operational rations, but its use was questioned because of toughness and lack of a typical cooked pork flavor. They also reported that both cooked and raw freeze-dried pork were sensitive to browning. Sharp (1957a)[8] stated that browning was due to the Maillard reaction, involving reducing sugars, protein, and amino acid constituents, Thomson et al. (1962)[9] stated that browning reactions can account for all of the undesirable characteristics observed during the storage of freeze-dried meats, with the exception of the development of rancidity.

Dehydrated meat and poultry with good storage stability and high acceptability after rehydrating and cooking are needed by the military and would have many civilian uses. As a step toward achieving such products, it was the purpose of this research to further define and correlate the major physical, chemical, and sensory changes which occur during the storage deterioration of precooked, diced, freeze-dried chicken, and raw and precooked sliced freeze-dried pork under very low oxygen and moisture conditions.

[7] Tuomy, J. M. and J. Felder. Effect of processing temperatures and cooking methods on the quality of freeze-dried pork. Food Technol. 18: 135 (1964).

[8] Sharp, J. G. Deterioration of dehydrated meat during storage. I. Nonenzymic deterioration in absence of oxygen at tropical temperatures. J. Sci. Food Agric. 8: 14 (1957a).

[9] Thomson, J. S., J. B. Fox, Jr. and W. A. Landmann. The effect of water and temperature on the deterioration of freeze-dried beef during storage. Food Technol. 16: 131 (1962).

MATERIALS AND METHODS

Preparation and freeze drying of product

Chicken. Freshly slaughtered commercial whole broiler breasts packed in ice were purchased from a local poultry plant. The breasts were cooked in 88°C water to an internal temperature of about 77°C, chilled in ice overnight, deboned, tempered to about -3°C and diced to 1.25 x 1.25 x 0.9-cm size with the largest surface area perpendicular to the direction of the fibers.

Raw and Cooked Pork. Fresh, bone-in loins having normal quality were purchased at a local meat packing plant and returned to the laboratory for further processing. The *longissimus* muscle was trimmed of excessive fat, tempered to -3°C and sliced in 1-cm thick slices perpendicular to fiber direction. For cooked pork, the trimmed *longissimus* muscle was stuffed in a moisture proof fibrous casing, cooked in 88°C water to an internal temperature of 77°C, chilled overnight at 2.0°C and sliced in 3-mm thick slices perpendicular to fiber direction.

Representative samples of the three types of product were removed for initial moisture analyses. All products were placed on stainless steel trays and frozen in a blast freezer set at -40°C.

Two lots of each product (22-27 kg) were freeze-dried in a Vacudyne Pilot Freeze-Dryer (Model VPFD-CX)* operating at a pressure of less than 600 microns. Heat was applied to the dryer trays by direct platen contact, with the platen temperature maintained at 47°C throughout the sublimation process. Forty to forty-four hours of drying were sufficient to yield a product with less than 2% moisture. Upon completion of drying, the chamber vacuum was released with high purity nitrogen, and samples of dried product were quickly removed for determination of residual moisture.

Packaging and storage

A standard amount (480 grams diced chicken; 520 gms of raw or cooked pork) of the dried product from each lot was weighed into No. 10 tin cans. Cans were sealed with a Rooney Semiautomatic Can Sealer** after evacuation and flushing three times with high purity nitrogen. To insure a zero oxygen atmosphere, the cans were punctured, placed in a desiccator and evacuated and flushed with nitrogen three times. Cans were resealed with solder and checked for leaks by submerging the cans in water under vacuum. The cans were randomly divided into groups for storage at various temperatures. Test samples were stored at 28°C; 38°C, and 48°C. Control or reference samples were packaged in a similar manner, and stored at -40°C. A randomly selected can from each lot at each storage temperature was opened for analysis after 1, 3, and 6 months of storage.

*Vacudyne Corp., 375 East Joe Orr Road, Chicago Heights, IL 60411.

**Rooney Machine Co., 423 Bayside Road, Bellingham, WA 98225.

Analytical Methods

All chemical analyses and physical measurements were performed in duplicate or triplicate. Moisture content of raw, cooked, and freeze-dried product was determined using standard AOAC methods (1955).[10]

Glucose was extracted from the freeze-dried product according to the procedure described by Hendrickson et al. (1955),[11] and the content of glucose determined by a modification of the glucose-oxidase method as described by Fleming and Pegler (1963).[12]

Lactic acid was determined using the procedure described in Sigma Technical Bulletin No. 826-UV, Sigma Chemical Company (1974).[13] This method is based on the enzymatic oxidation of lactic acid to pyruvic acid mediated by NAD and LDH.

Content of ε-amino nitrogen groups was determined by the trinitrobenzene sulfonic acid (TNBS) method for available lysine (Kakade and Liener, 1969),[14] as used by Ousterhout and Wood (1970).[15] Modifications were made in the procedure to accommodate a smaller sample size.

[10] AOAC. Official Methods of Analysis, 10th Edition, Association of Official Agricultural Chemists, Washington, DC (1965).

[11] Hendrickson, R. L., D. E. Brady, C. W. Gehrke, and R. F. Brooks. Dehydrated pork studies: Removal of glucose by yeast fermentation. Food Technol. 9: 290 (1955).

[12] Fleming, I. E. and H. F. Pegler. The determination of glucose in the presence of maltose and isomaltose by a stable, specific enzymic reagent. Analyst 88: 967 (1963).

[13] Anonymous. The quantitative determination of pyruvic acid and lactic acid. Sigma Technical Bulletin No. 726 - UV/No. 826-UV. Sigma Chemical Company, St. Louis (1974).

[14] Kakade, M. L. and I. E. Liener. Determination of available lysine in proteins. Analytical Biochem. 27: 273 (1969).

[15] Ousterhout, L. E. and E. M. Wood. Available lysine in fish meals: Chemical (TNBS) method compared with a chick assay. Poultry Sci. 49: 1423 (Abstract) (1970).

Reducing substances, expressed as ascorbic acid, were determined by a modification of the method of Loeffler and Ponting (1942).[16] Reducing substances were extracted from the product by mixing 0.5 g of ground freeze-dried meat with 10 ml of 1% metaphosphoric acid and centrifuging the resultant slurry. The reduction of a standard 2,6-dichlorophenolindophenol dye solution by an aliquot of the extract was determined quantitatively and calculated as an equivalent amount of ascorbic acid, a typical reductone.

Analysis of headspace gas of each can was made just prior to opening the cans of stored product for sensory evaluation. Samples were taken and pressures were determined with a Beckman Headspace Sampler.* Oxygen and carbon dioxide content of headspace gas were determined by standard Orsat procedures.

Surface color reflectance values were determined with the Hunter Color and Color Difference Meter (D-25-D)** equipped with a 5-cm circular port. Shortly after opening the cans of stored products for sensory evaluation, representative samples of the product were rehydrated in an excess of water (chicken at 100°C for 20 minutes; raw pork at 38°C for 20 minutes; and cooked pork at 94°C for 20 minutes) drained for 5 minutes and the reflectance values determined using the Hunter Meter.

Rehydration and preparation of samples for sensory evaluation

Approximately 750 ml of distilled water was brought to a boil, 100 g dry freeze-dried chicken were added, and heat reduced so that the water was boiling slowly. After 20 minutes, water was poured off and chicken allowed to drain and cool 5 minutes before weighing. Approximately 18 g of the rehydrated samples was used as an individual portion for sensory tests.

Slices of raw pork were rehydrated in water (28-38°C) for 20-25 minutes, drained, weighed, and grilled 2 minutes on each side in electric skillets set at 193°C. Cooking oil (100 ml) was used to coat the skillets. Slices were cut into pieces approximately 2.5 cm square. A test portion consisted of 2 to 3 squares.

Slices of cooked freeze-dried pork were rehydrated in water at 94-100°C for 20-25 minutes, turning once after 10 minutes. Slices were cut into

* Beckman Instruments, Inc., 2500 Harbor Blvd, Fullerton, CA 92634.

**Hunter Associates Laboratories, Inc., 9529 Lee Highway, Fairfax, VA 22030.

[16] Loeffler, H. J. and J. D. Ponting. Ascorbic Acid - Rapid determination in fresh, frozen, or dehydrated fruits and vegetables. Ind. and Eng. Chem. Anal. Ed. 14: 846 (1942).

pieces approximately 2.5 cm square. Test portion consisted of 2 to 3 squares.

Percent rehydration (gross rehydrated weight as a percentage of the gross initial weight before freeze-drying) was calculated from the data obtained during reconstitution of the product for sensory evaluation and from moisture contents before and after freeze-drying. Percent rehydration was calculated according to the formula used by Osman and Morse (1960),[17] which included a correction for the moisture content of the freeze-dried product.

Sensory Evaluation

The triangle test with categorical basis for selection was used to determine if there were differences in the freeze-dried products stored at three temperatures compared to the control sample stored at -40°C. A number of panelists participated in orientation and screening sessions using products similar to the ones to be tested. On the basis of performance in selecting the odd sample (i.e. at least 70% accurate), 8 panelists and 2 alternates were chosen to participate as descriminating panelists in evaluating test products after 1, 3, and 6 months storage. Panelists evaluated two sets of samples at each session, with 2 sessions being held each day (4 reps).

For the 1- and 3-month storage samples, triangle tests combined with a descriptive term (appearance, texture, juiciness, etc.) were used as a basis for selection and characterization of the odd sample. For the 6-month storage samples, triangle tests combined with scoring of seven parameters were used to evaluate effects of storage temperature and time. For each set of samples, panelists selected the odd sample and then scored the odd sample and same samples for tenderness, mealiness, fibrousness, wetness, darkness, off-flavor, and desirability, using an intensity scale from 0 (none or not applicable) to 4 (extremely). Scoring data were recorded and then analyzed by the "t" test for paired observations only for the panelists who correctly identified the odd-sample. Triangle test data were interpreted from the tables of Roessler (Amerine et al., 1965).[18]

[17]Osman, O. A. H. and R. E. Morse. Preparation and storage characteristics of freeze dried sausages. I. Formulation and processing of comminuted sausages (frankfurters). Food Technol. 14: 37 (Abstract) (1960).

[18]Amerine, M. A., R. M. Pangborn, and E. P. Roessler. Principles of Sensory Evaluation of Foods. Academic Press, New York 602 pp. (1965).

RESULTS & DISCUSSION

Headspace Gas Analysis

Within the accuracy of the Orsat apparatus ($\leq 0.2\%$), no carbon dioxide or oxygen could be detected in the headspace of any of the cans of product for all storage temperatures and storage times. The zero oxygen level in the headspace confirmed the adequacy of nitrogen packing and can tightness. The lack of carbon dioxide production in our study is in contrast to the results of Sharp (1957a)[19] who noted production of carbon dioxide in freeze-dried precooked pork stored in nitrogen at high relative humidities, and as reported by Hodge (1953)[20] in a review of browning reactions in model systems. The lack of carbon dioxide production may have been due to the low residual moisture content or other conditions that inhibited the Strecker degradation; i.e. conversion of ϵ-amino acids to aldehydes containing one less carbon, with the liberation of carbon dioxide.

Residual Moisture Content

The average residual moisture content of the three types of freeze-dried products is shown in Table 1. There were no appreciable changes in residual moisture content during the 6-month storage period. Before freeze-drying, cooked chicken contained 72.7% moisture, raw pork 69.9% moisture, and cooked pork 63.3% moisture. The mean residual moisture content of the six lots of freeze-dried product, immediately after removal from the freeze drier, was 0.75% with a range from 0.57 to 0.92. The mean moisture content of all products taken from cans over the 6 month period was 1.09%, with a standard deviation of 0.29. In only one instance (raw pork, Lot 1, 38°C storage for 1 month) did this absorption result in a product moisture level greater than 2.0%. Apparently the products absorbed a small amount of atmospheric moisture in transfer from drier to can. The increase cannot be explained on the basis of the water formed from the hypothetical loss of 3 moles of water per mole of glucose degraded, because this would contribute less than 0.03% water content, at a maximum.

Glucose Content

Substantial, increasing losses of glucose (Table 2) occurred with increasing temperatures and time of storage for cooked chicken, raw and

[19] See footnote 8

[20] Hodge, J. E. Dehydrated foods chemistry of browning reactions in model systems. J. Agric. Food Chem. 1: 928 (1953).

cooked pork, with little or none remaining after 6 months at 48°C. More rapid losses of glucose were noted by Sharp (1957a)[21] in samples of dehydrated cooked pork, but at much higher relative humidities than ours. He reported an initial concentration of free fermentable sugar in samples of dehydrated cooked pork equilibrated at 60% RH of 0.26% of which 0.18% was glucose. After 60 days at 37 and 50°C, no free sugar could be detected in the meat.

The rates of loss of glucose in the freeze-dried chicken over the six-month storage period was used to calculate the temperature coefficient and corresponding energy of activation. The loss of glucose over the six-month period corresponded to first-order reactions for the three experimental storage temperatures. The temperature coefficient Q_{10} was 2.8, equivalent to an energy of activation of about 20 kcal/mole. Regier and Tappel (1956b)[22] reported an apparent activation energy of 25 kcal/mole for the deterioration of freeze-dried beef during storage at several temperatures.

Glucose data for cooked chicke and cooked pork were subjected to analysis of variance; data for raw pork were not analyzed because of missing data in the critical temperature region. Food cooked chicken, all main effects (temperature, time, lot) were highly significant ($P < 0.01$), and interactions were also significant. The important effects were obviously temperature and the temperature multiplied by the time interaction. Similar results were obtained from an analysis of variance of the cooked pork data, but with relatively less influence of time.

Lactic Acid Content

The mean values for lactic acid content of freeze-dried samples are shown in Table 3. The lactic acid content of freeze-dried samples was essentially the same for all temperatures and length of storage, as determined by analysis of variance of the experimental values. Overall means, in mg lactic acid per gram of dry product, were 22.7 for cooked chicken, 28.8 for raw pork, and 21.4 for cooked pork. There was a significant difference between the two lots of chicken, 20.3 versus 25.2. The absence of storage related changes in lactic acid content does not rule out its participation in deteriorative reactions, because the molal content of lactic acid

[21] See footnote 8.

[22] Regier, L. W. and A. L. Tappel. Freeze dried meat. IV. Factors affecting the rate of deterioration. Food Res. 21: 640 (1956b).

is about 100 times the initial molal content of glucose, and small changes (say less than 1%) in lactic acid would not be detected by the analytical method. The question of lactic acid involvement has been raised by Lewis et al. (1949)[23] who reported formation of brown pigments from interaction of glucose and nitrogen-free hydroxy acids, and by Sharp (1957a)[24] who found no effect on browning by additions of lactic acid to a mixture of insoluble pork protein and glucose. However, Sharp's tests were run at 60% relative humidity, which is quite atypical and far removed from the much less than 5% relative humidity existing in our freeze-dried products.

ε-Amino Nitrogen Content

The mean values for ε-amino nitrogen content of the three types of freeze-dried samples are shown in Table 4. The ε-amino nitrogen content was from 100 to 200 times the initial glucose content on a molal basis, and displayed no statistically significant differences due to storage temperature, storage time, or lot. The overall mean ε-amino nitrogen content under all conditions was in millimoles per gram dry weight, 0.48 for cooked chicken, 0.45 for raw pork, and 0.42 for cooked pork. Due to the overwhelming proportion of ε-amino nitrogen content to glucose, a 1-to-1 molal reaction between the two could have taken place without being statistically detectable in changes in the ε-amino nitrogen content.

Reducing Substances Expressed as Ascorbic Acid

Changes in the content of reducing substances, expressed as ug equivalents of ascorbic acid, a known reductone, are shown in Table 5. The data were analyzed by analysis of variance. For freeze-dried chicken, level of reducing substances increased significantly ($P < 0.01$) as a function of storage temperature and time, and also differed significantly between lots. For raw freeze-dried pork slices, there were significant differences between temperature ($P < 0.01$) and between times ($P < 0.05$). For cooked pork, there were significant differences between temperatures ($P < 0.01$), times ($P < 0.01$), lots ($P < 0.05$), and temperature by time interaction ($P < 0.01$). The maximum molal content of reducing substances formed corresponds to 15-30% of initial molal glucose content.

The development of reductone like reducing power is a well-known characteristic of sugar-amine browning reactions (Stadtman, 1948).[25] The

[23] Lewis, V. M., W. B. Esselen, Jr. and C. R. Fellers. Nitrogen-free carboxylic acids in the browning reaction. Ind. Eng. Chem. 41: 2591 (1949).

[24] See footnote 8.

[25] Stadtman, E. R. Non-enzymatic browning in fruit products. Adv. in Food Res. 1: 325 (1948).

structures of the reductones formed during sugar degradation are not known with certainty, and in only a few model systems has the browning of reductones with amines been studied (Cocker et al., 1950).[26] Therefore, it should be of importance to search for and quantitatve intermediates in the sugar-amine browning reaction such as ketosamines, osones, and reductones.

Color Changes

The panel easily detected darkening in the 48°C samples of cooked chicken and cooked pork compared to the -40°C (Control) samples after one month. After three months of storage, darkening was detected in the 38°C samples of all three products, and in the 28°C samples of raw pork after six months of storage. The reactions leading to color changes obviously had high temperature coefficients. These findings agree with those of Sharp (1957b)[27] who observed an increase in the development of brown discoloration with an increase in temperature of storage. Similar observations were reported by Regier and Tappel (1956a)[28] for beef stored at 35.5 and 54.4°C.

Tables 6, 7, and 8 give the mean Hunter Color Values for cooked diced chicken, raw sliced pork and cooked sliced pork, respectively. The decrease in L values (lightness) of cooked chicken and cooked pork agree with the visual observations of darkening. For cooked chicken, effects of storage time on L values were inconsistent, but definite decreases in L values with increasing storage temperature were observed at 3 and 6 months. For cooked pork, there were small but statistically significant ($P < 0.01$) decreases in L values with increases in either storage time or storage temperature. Differences in L values between lots were significant at the 5% level. For raw pork, there was a small, statistically significant ($P < 0.01$) decrease in L value with increase in storage time. Differences in L values of raw pork between storage temperatures were significant ($P < 0.01$), but they were not simply explained, since highest values appear at the two intermediate temperatures.

The Hunter a_L values, a measure of redness, exhibited much greater percentage variation than did the L values, with a range from 1 to 5. For cooked chicken, a_L values increased with increase in storage temperature, and with increase in storage time at 38 and 48°C storage temperatures. For cooked pork,

[26] Cocker, W., R. A. Q. O'Meara, J. C. P. Schwartz, and E. R. Stuart. The chemistry of reductone. Part II. Some condensation products of reductone with amino compounds. J. Chem. Soc. No. 420: 2052 (1950).

[27] Sharp. J. G. Deterioration of dehydrated meat during storage. II. Effect of pH and temperature on browning changes in dehydrated aqueous extracts. J. Science Food Agric. 8: 21 (1957b).

[28] See footnote 1.

there was a significant ($P < 0.01$) consistent large increase in a_L values with increase in temperature; in comparison, effects of storage time were small and inconsistent. For raw pork, there were significant differences in a_L values between temperatures and between times, but the trends were not consistent, and so the overall meaning is questionable.

Hunter b_L values, a measure of yellowness, increased slightly but significantly with increases in storage temperature for all three products, and showed essentially no change with increase in storage time.

Based on observations of the senior author, color of cooked diced chicken changed from a pale pinkish tan to a dark yellowish tan. Similar changes occurred in cooked pork. For raw pork, the color changed from a reddish tan to a reddish-brown tan.

Rehydration

Rehydration values (percent rehydration based on gross rehydrated weight as a percentage of the gross initial weight) for cooked diced chicken, raw and cooked pork are given in Table 9. There was no significant change in percent rehydration of the freeze-dried products due to storage temperature or time. The data show that precooked freeze-dried chicken and pork slices have relatively poor rehydration characteristics. According to Tappel et al. (1955),[29] Harper and Tappel (1957),[30] and Hamdy et al. (1959)[31] poor rehydration is one of the principal problems in freeze-dried meats. In our study, percent rehydration ranged from 70.6 to 84.9% for chicken; 52.3 to 100% for raw pork slices, and 63.6 to 75.2% for cooked pork slices. In general, cooked pork slices rehydrated to a much lower level than raw pork slices. Tappel et al. (1957)[32] rehydrated precooked freeze-dried chicken thigh meat in a bouillon.

[29] Tappel, A. L., A. Conroy, M. R. Emerson, L. W. Regier, and G. F. Stewart. Freeze-dried meat. I. Preparation and properties. Food Technol. 9: 401 (1955).

[30] See footnote 2.

[31] Hamdy, M. K., V. R. Cahill, and F. E. Deatherage. Some observations on the modification of freeze-dehydrated meat. Food Res. 24: 79 (1959).

[32] See footnote 3.

sodium chloride, sodium pyrophosphate solution and obtained a rehydrated water content that was 68% of the original water content before freeze-drying. This value converts to 76.8% in Osman units (gross rehydrated weight over original weight before freeze-drying, times 100), which compares well with the values in Table 9 that we obtained for precooked chicken breast meat without use of salts. Yao et al. (1956)[33] reported for freeze-dried precooked chicken breast meat a value of 74% for the rehydration ratio defined as the ratio of water absorbed by the dehydrated sample to water lost by the sample during drying.

The relatively low rehydration values cannot be attributed to inferior muscle fiber to surface orientation (Anglemier et al., 1960)[34] because both chicken dices and pork slices were cut with the fibers perpendicular to the greatest surface, the optimum orientation for rehydration.

Sensory Evaluation

Upon opening of the cans for rehydration tests and ultimate panel evaluation of the product, a stale and somewhat rancid odor was found to be characteristic of the samples stored at the higher temperatures. The intensity of these odors increased with storage time. Similar observations of off-odors were reported by Burnett et al. (1955)[35] for cooked freeze-dried pork; and Chipault et al. (1961)[36] for freeze-dried chicken.

Table 10 shows panel results of the triangle tests for cooked diced freeze-dried chicken. Sensory evaluation of the differences between control samples at -40°C and samples at the three experimental temperatures revealed detectable deterioration in the 48°C samples at 1 month and thereafter, and in the 38°C samples at 3 months and thereafter. The 38 and 48°C samples were less tender, more fibrous, darker, and drier than the -40°C samples. Significant differentiation of 28 and -40°C samples was established at 3 months, but not at 1 and 6 months, so an overall effect for 28°C seems questionable.

Scores given by panelists who successfully differentiated the -40°C controls from experimental temperature samples are summarized and evaluated

[33]Yao, A., A. I. Nelson, and M. P. Steinberg. Factors affecting the rate of chicken meat dehydration under vacuum. Food Technol. 10: 145 (1956).

[34]Anglemier, A. F., D. L. Crawford, and H. W. Schultz. Improving the stability and acceptability of precooked freeze-dried ham. Food Technol. 14: 8 (1960).

[35]Burnett, M. C., C. W. Gehrke, and D. E. Brady. Volatile components of vacuum packed dehydrated pork. J. Agr. Food Chem. 3: 524 (1955).

[36]Chipault, J. R., J. M. Hawkins, and E. McMeans. Factors controlling rancidity development in freeze-dried meats. A.M.F. and C.I. Contract No. DA 19-129-QM-1725. File No. A-339. (1961).

in Table 11 for cooked chicken. No significant effect for any of the seven qualities was observed for 28°C versus -40°C. Samples at 38°C were significantly darker than -40°C controls, and there were good indications that they were less tender, more fibrous, and less desirable than -40°C samples. Samples at 48°C were significantly less tender, darker, and more off-flavored than controls, and there was a good indication that they were less desirable than -40°C controls.

Table 12 shows panel results of triangle tests for raw and cooked freeze-dried pork slices. For raw pork, there were easily detectable and highly significant changes at 38 and 48°C at 3 months and thereafter. Based on scoring data, for raw pork stored for 6 months (Table 13), the 28°C samples were not significantly different from the controls. The 38°C samples were significantly darker and less desirable than -40°C controls, and there were good indications that they were less tender, more fibrous and drier. The 48°C samples were significantly less tender, more fibrous, drier, darker, more off-flavored and less desirable than the controls. It was more difficult to detect differences in the raw freeze-dried pork samples because grilling after rehydration masks much of the color difference and renders both the treated and control samples dry.

Significant changes were detected in the cooked freeze-dried pork slices at 1, 3, and 6 months for all three temperatures, with the degree of significance increasing as the experimental temperature increased. On the basis of the scoring data (Table 14), compared to the -40°C controls, there were no significant effects for 28°C samples, an indication of greater darkness in 38°C samples. The 48°C samples were significantly more fibrous, drier, darker, more off-flavored, and less desirable and were less tender and less mealy than the controls.

CONCLUSIONS

The results of this investigation indicate that excessive (38, 48°C) temperatures for three to six months were required to develop serious deterioration in freeze-dried chicken and pork at 1% moisture and 0% oxygen level. Color, tenderness, and flavor were affected.

Rehydration capacity of freeze-dried cooked chicken and raw and cooked pork at 1% moisture content was not influenced by storage in nitrogen at temperatures as high as 48°C and for periods as long as 6 months. Improvements in rehydration should be sought in pretreatment and freeze-drying steps.

ε-amino nitrogen content was 100- and 200-fold that of glucose on a molal basis, and experienced no detectable change over six months at temperatures up to 48°C. Loss of 1 mole amino nitrogen per 1 mole of glucose probably could not have been established within the accuracy of the analytical methods. Based on the molal ratio of ε-amino nitrogen to glucose in some meats found here, the molal ratios used in most model system studies, say 0.5 to 5, are unrealistic and may lead to erroneous conclusions about the behavior of natural products.

Reducing substances, as measured by 2,6-dichlorophenolindophenol, accumulated to 15-30% of initial glucose level on a molal basis after 6 months at 48°C and may be a good chemical indicator of deterioration.

This document reports research undertaken at the US Army Natick Research and Development Command and has been assigned No. NATICK/TR-78/007 in the series of reports approved for publication.

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ADDENDUM

The Effect of Soaking Chicken Breasts in Salt/Phosphate Solutions on Improving Rehydration

THE EFFECT OF SOAKING CHICKEN BREASTS IN SALT/PHOSPHATE SOLUTIONS ON IMPROVING REHYDRATION

INTRODUCTION

Results of the study to identify the components or fractions associated with adverse changes in freeze-dried chicken and pork during storage indicate that the rehydration values obtained agree with those of previous investigators, and that precooked freeze-dried poultry and pork rehydrate rather poorly.

According to Tappel et al. (1955),[37] Harper and Tappel (1957),[38] Hamdy et al. (1959),[39] Tuomy and Felder (1964),[40] Tuomy and Helmer (1967),[41] and Hinnergardt et al. (1975),[42] dry texture and poor rehydration are the principal problems in freeze-dried meat.

Various attempts have been made to improve the rehydration of meat. Hamdy et al. (1959)[43] tried to improve rehydration of freeze-dried meats by rehydrating them in solutions of 0.2 M NaCl, 0.01 M KCl and 0.05 M sodium ascorbate. These treatments seemed to improve the texture and water-holding capacity (WHC) of the freeze-dried meats. Hinnergardt et al. (1975)[44] undertook a

[37] See footnote 29.

[38] See footnote 2.

[39] See footnote 31.

[40] See footnote 7.

[41] Tuomy, J. M. and R. L. Helmer. Effect of freeze-drying on the quality of the _longissimus dorsi_ muscle of pork. Food Technol. 21: 167 (1967).

[42] Hinnergardt, L. C., S. R. Drake, and R. A. Kluter. Grilled freeze-dried steaks. Effects of mechanical tenderization plus phosphate and salt. J. Food Sci. 40: 621 (1975).

[43] See footnote 31.

[44] See footnote 42.

study to determine the effect of a phosphate and salt solution in combination with mechanical tenderization of beef prior to cooking and freeze-dehydration on the juiciness, tenderness, and rehydration of precooked freeze-dried steaks. Phosphate-salt treatments, with or without mechanical tenderization, increased tenderness and juiciness, and raised final percent moisture from 50 to 56%.

The objective of this portion of the project was to determine the effect of soaking chicken breasts prior to and after cooking in salt (NaCl)/phosphate solutions on improving the rehydration characteristics of precooked diced, freeze-dried chicken.

MATERIALS AND METHODS

Two hundred eviscerated and washed broilers, totaling 500 pounds, were removed from a commercial processing line at a location just before the chiller and transported in ice to the laboratory. Three hours postmortem the breast meat (Pectoralis major and minor) was cut from the chilled carcasses, divided into two equal lots, I and II, and soaked in water, and a solution containing 3% Kena plus 4% sodium chloride, respectively. After three hours, the meat was drained free of solution and held at 3°C overnight. Meat was then cooked in 89°C water to an internal temperature of 77°C, drained and chilled in 3°C air for two hours. Each lot was then divided into two equal sub-lots, 1a and 1b, and 2a and 2b, the a's being chilled in 3°C air for three hours, and the b's chilled in a 3°C solution containing 3% Kena and 4% sodium chloride, for three hours. The four sub-lots were drained free of solution, diced to dimensions of 1.25 x 1.25 x 0.95 cm frozen on trays in a -23°C air blast freezer, and freeze-dried in a pilot size freeze-dryer at a pressure of 250 microns, condenser temperature of -40°C to -51°C, and platen temperature of 49°C. Vacuum was released with high purity nitrogen, the dry product was nitrogen packed in No. 2-1/2 tin cans, and stored at -34°C.

Determinations were made of yields, moisture contents, rehydration capacity, and phosphorus and chloride contents. Approximately 20 grams of accurately weighed, diced, freeze-dried material was soaked in 150 ml of 80°C distilled water for 20 minutes, drained for five minutes, and weighed. Water was expressed from the rehydrated samples by a 500-kg Instron activated force acting through a 105-sqcm plunger on about 20 grams of sample.

Phosphorus and chloride contents were determined by AOAC methods.[10]

[45] See footnote 10.

RESULTS AND DISCUSSION

Table 15 summarizes the effects of phosphate-salt treatments prior to and after cooking on water pick-up, cooked yields, and rehydration capacity of the freeze-dried products. As expected, the use of polyphosphates with salt increased the water pick-up by about 8 percent, and cooked yield based on original unsoaked weight was 13 percent due to the polyphosphate-salt treatment. Polyphosphate-salt treatment of sub-lots of lots 1 and 2 produced only 5 percent water pick-up. Percentage moisture in the frozen, precooked samples was 7.4 percent higher in the polyphosphate-salt treated lot 2b than in the control 1a. When the four lots were freeze-dried to moisture levels below 0.3 percent and rehydrated, lot 2b which received two phosphate-salt treatments held 4 percent more water than the control and lost 5 percent less water under pressure. The 4 percent additional water at the 64 percent initial level may be compared to Hinnergardt's (1975)[46] 6 percent addition by phosphate-salt at the 50 percent initial level.

Table 16 summarizes data on the mineral content of the four products. Increases in ash content are substantial and cannot be accounted for entirely as increases in Kena plus sodium chloride. Somewhat more chloride and phosphorus were incorporated into the meat by treatment before cooking than by treatment after cooking.

[46] See footnote 42.

Table 1. Moisture content (percent) of freeze-dried chicken and pork stored for 1, 3, and 6 months

	Storage Temperature and Time											
	-40°C (Control)			28°C			38°C			48°C		
Product	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo
Cooked diced chicken												
Lot I (0.57)*	1.22	0.84	0.87	0.83	0.83	1.18	1.19	0.95	0.93	1.06	1.33	0.69
Lot II (0.92)*	1.08	1.25	1.14	1.17	1.00	1.43	1.25	1.09	1.10	1.05	0.94	1.09
Raw sliced pork												
Lot I (0.74)*	1.19	1.48	1.06	1.05	1.19	1.17	2.26	1.06	0.87	1.24	1.25	0.99
Lot II (0.88)*	1.18	1.06	1.52	1.11	1.21	0.82	1.75	1.24	0.90	1.07	1.34	0.94
Cooked sliced pork												
Lot I (0.80)*	0.82	1.19	0.72	1.64	0.97	0.93	1.02	0.99	1.38	0.81	1.50	0.77
Lot II (0.57)*	0.92	2.00	0.72	0.68	0.81	0.72	1.44	1.00	0.76	0.73	1.06	0.86

*Values of dehydrated product immediately out of freeze-dryer.

Table 2. Glucose content (mg/100 g dry product) of freeze-dried chicken and pork stored for 1, 3, and 6 months*

Product	Storage Temperature and Time											
	-40°C (Control)			28°C			38°C			48°C		
	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo
Cooked diced chicken												
Lot I	25	40	34	37	21	12	16	5	3	6	1	0
Lot II	43	46	50	50	19	21	17	10	4	6	1	0
Raw sliced pork												
Lot I	51	49	60	45	53	29	37	—	6	6	—	7
Lot II	50	38	60	43	31	23	43	—	15	16	—	5
Cooked sliced pork												
Lot I	80	61	78	78	81	81	48	71	61	17	28	3
Lot II	90	78	76	74	31	66	30	13	15	5	7	3

*Values are mean of three determinations from three five-gram samples.

Table 3. Lactic acid content (mg/gram dry product) of freeze-dried chicken and pork stored for 1, 3, and 6 months*

	Storage Temperature and Time											
	-40°C (Control)			28°C			38°C			48°C		
Product	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo
Cooked diced chicken												
Lot I	20	19	21	17	20	20	23	24	22	19	20	19
Lot II	24	24	26	25	24	29	26	25	24	27	24	24
Raw sliced pork												
Lot I	23	24	32	28	31	29	28	24	23	32	28	31
Lot II	34	30	29	31	30	30	32	20	29	37	27	29
Cooked sliced pork												
Lot I	18	20	24	23	23	21	24	23	23	21	21	20
Lot II	17	22	22	19	23	22	21	19	22	23	21	22

*Values are mean of 3 determinations.

Table 4. ε-Amino nitrogen content (millimoles/gram dry weight) of freeze-dried chicken and pork stored for 1, 3, and 6 months*

Product	-40°C (Control)			28°C			38°C			48°C		
	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo
Cooked diced chicken												
Lot I	.48	.43	.56	.51	.42	.52	.45	.45	.51	.47	.49	.49
Lot II	.49	.43	.56	.47	—	.55	.45	.41	.54	.48	.45	.49
Raw sliced pork												
Lot I	.53	.50	.42	.52	.42	.40	.52	.42	.50	.52	.41	.48
Lot II	—	.41	.45	—	.40	.40	—	.40	.45	—	.37	.43
Cooked sliced pork												
Lot I	.46	.50	.34	.42	—	.38	.40	.40	.25	.42	.43	.19
Lot II	.42	.49	.49	.45	.39	.57	.35	.40	.12	.40	.41	.30

*Values are means of two determinations.

Table 5. Reducing substances, as μg equivalent ascorbic acid per gram dry product of freeze-dried, chicken and pork stored for 1, 3, and 6 months*

Product	Storage Temperature and Time											
	-40°C (Control)			28°C			38°C			48°C		
	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo
Cooked diced chicken												
Lot I	—	11	28	14	29	44	35	46	58	39	67	71
Lot II	11	18	30	18	—	52	41	59	71	51	77	103
Raw sliced pork												
Lot I	0	2	0	0	2	0	0	23	53	11	17	139
Lot II	0	0	0	0	3	2	0	25	52	11	138	128
Cooked sliced pork												
Lot I	0	1	5	0	—	15	5	14	83	12	95	117
Lot II	0	0	2	0	0	7	9	1	42	7	41	68

*Values are means of six determinations.

Table 6. Effect of storage temperature and time on Hunter Color Values of rehydrated freeze-dried cooked diced chicken

Storage Temperature °C	Lot Number	1-Month Hunter Values* L	1-Month a	1-Month b	3-Months Hunter Values L	3-Months a	3-Months b	6-Months Hunter Values L	6-Months a	6-Months b
-40(Control)	I	56.2	2.0	15.0	59.2	0.2	13.2	60.5	-0.5	13.4
	II	-	-	-	55.3	1.5	14.6	58.9	+0.1	14.6
28	I	-	-	-	58.4	0.2	14.2	59.4	-0.1	14.2
	II	-	-	-	-	-	-	59.2	+0.3	15.2
38	I	59.0	1.4	15.0	53.3	1.5	14.4	55.3	2.0	15.1
	II	57.0	1.5	15.6	50.0	2.8	14.4	53.5	2.8	15.6
48	I	52.9	2.8	15.6	54.2	2.3	15.1	50.8	3.1	15.3
	II	-	-	-	51.9	3.7	16.0	48.6	3.7	15.4

* Hunter Color Values.
L - Measures lightness and varies from 100 for perfect white to zero for black.

a - Measures red when plus and green when minus.

c - Measures yellow when plus and blue when minus.

Table 7. Effect of storage temperature and time on Hunter Color Values of rehydrated freeze-dried sliced raw pork

Storage Temperature °C	Lot Number	Months of Storage								
		1-Month			3-Months			6-Months		
		Hunter values*			Hunter values			Hunter values		
		L	a	b	L	a	b	L	a	b
-40(Control)	I	56.5	5.2	10.0	57.0	3.7	10.5	47.6	4.9	9.0
	II	59.5	3.9	9.6	54.2	4.5	10.1	50.1	6.2	10.1
28	I	55.0	5.1	11.2	60.5	2.0	11.2	57.8	3.9	11.9
	II	—	—	—	59.8	2.7	11.1	55.4	3.6	11.7
38	I	61.9	2.7	11.9	57.9	2.4	12.8	53.5	3.4	12.8
	II	61.3	2.3	13.7	57.4	3.3	14.9	55.9	3.8	15.1
48	I	57.2	3.9	13.0	51.5	2.9	14.0	51.2	4.0	12.9
	II	57.6	4.1	13.0	40.7	5.3	12.7	50.6	4.2	13.3

*Hunter Color Values.
L - Measures lightness and varies from 100 for perfect white to zero for black

a - Measures red when plus and green when minus

b - Measures yellow when plus and blue when minus

Table 8. Effect of storage temperature and time on Hunter Color Values of rehydrated freeze-dried cooked sliced pork

Storage Temperature °C	Lot Number	Months of Storage								
		1-Month			3-Months			6-Months		
		Hunter Values*			Hunter Values			Hunter Values		
		L	a	b	L	a	b	L	a	b
-40(Control)	I	62.7	0.7	11.4	65.0	1.0	12.0	64.4	0.4	11.2
	II	65.1	1.0	11.0	63.2	0.9	11.5	63.1	1.3	12.2
28	I	64.8	0.8	11.2	62.2	1.8	12.2	60.9	1.2	12.7
	II	63.0	1.4	12.0	62.9	1.3	11.7	60.2	0.9	12.9
38	I	60.4	1.7	12.9	61.2	2.7	12.6	59.0	2.8	13.2
	II	59.7	1.4	12.5	53.6	2.2	11.9	51.0	2.4	13.1
48	I	59.8	2.3	13.3	52.9	4.2	14.0	54.6	4.0	13.2
	II	60.3	3.2	13.2	50.9	4.3	12.7	49.7	4.5	14.3

*Hunter Color Values
L - Measures lightness and varies from 100 for perfect white to zero for black

a - Measures red when plus and green when minus

b - Measures yellow when plus and blue when minus

Table 9. Effect of storage time and temperature on (percent) rehydration of freeze-dried chicken and pork[a]

	Storage Temperature and Time											
	-40°C (Control)			28°C			38°C			48°C		
Product	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo
Cooked diced chicken												
Lot I	77.6	76.2	78.2	75.2	74.4	74.3	77.1	79.9	79.3	80.4	76.3	72.2
Lot II	77.9	74.8	72.2	74.6	84.1	84.9	71.9	72.9	75.7	71.7	70.6	75.3
Raw sliced pork												
Lot I	84.6	87.3	88.2	87.1	100.0	83.3	87.8	90.8	86.0	100.0	74.6	52.3[b]
Lot II	86.8	84.4	87.8	93.1	83.6	81.3	70.3	88.9	84.1	93.6	82.4	70.8
Cooked sliced pork												
Lot I	68.6	63.6	69.7	74.4	73.2	71.5	70.9	69.9	73.2	66.1	70.4	75.2
Lot II	65.8	67.7	69.0	72.7	73.1	68.5	68.1	64.0	71.3	70.0	68.1	67.1

[a]Percent rehydration is gross rehydrated weight divided by gross initial weight before freeze-drying x 100.

[b]Based on all other data, the validity of this value is questioned. Insufficient sample material prevented a repeat of rehydration of this sample under the conditions used for the original sample.

Table 10. Panel results of triangle test for freeze-dried cooked chicken after 1, 3, and 6 months of storage

	Storage Temperature and Time								
	-40°C vs 28°C			-40°C vs 38°C			-40°C vs 48°C		
Product	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo
Cooked diced chicken									
Session I (2 reps)	7	10[a]	6	5	7	18[b]	7	15[b]	18[b]
Session II (2 reps)	5	7	7	9[a]	10[a]	13[b]	10[a]	14[b]	16[b]
Combined (4 reps)	12/32	17[a]/32	13/36	14/32	17[a]/32	31[b]/34	17[a]/32	29[b]/32	34[b]/34

[a]Significantly different - 5% level.

[b]Significantly different - 0.1% level.

Table 11. Mean scores and differences, and significance of differences between paired scores for freeze-dried cooked chicken after 6 months of storage[a]

Temperature Effect	Tenderness	Mealiness	Fibrousness	Wetness	Darkness	Off-Flavor	Desirability
	Sensory Parameter						
$28^{o}C$	2.38	1.62	1.15	2.08	1.08	0.46	2.23
$-40^{o}C$	2.54	1.69	1.31	2.15	0.92	0.54	1.92
Difference	-0.16	-0.07	-0.16	-0.07	+0.16	-0.08	+0.31
Significance[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
$38^{o}C$	1.84	1.58	1.81	2.23	1.97	0.61	1.52
$-40^{o}C$	2.84	1.48	1.10	2.35	0.77	0.45	2.10
Difference	-1.00	+0.10	+0.71	-0.12	+1.20	+0.16	-0.58
Significance	≠	N.S.	≠	N.S.	*	N.S.	≠
$48^{o}C$	1.47	1.74	2.03	2.09	2.62	1.09	1.09
$-40^{o}C$	2.29	1.62	1.65	2.32	0.71	0.44	1.97
Difference	-0.82	+0.12	+0.38	-0.23	+1.91	0.65	-0.88
Significance	*	N.S.	N.S.	N.S.	*	**	≠

[a] Rehydrated cooked chicken scored by nine panelists in two sessions with two replicates per session. 0 = none, 4 = extreme.

[b] Significance of differences between temperatures tested by t test for paired observations.

* Significant at 1% level.

** Significant at 5% level.

≠ Significant (1%) overall, but only significant in one of two sessions treated separately.

NOTE: N.S. means non significant.

Table 12. Panel results of triangle test for freeze-dried raw and cooked pork slices after 1, 3, and 6 months of storage

Product	Storage Temperature and Time								
	-40°C vs 28°C			-40°C vs 38°C			-40°C vs 48°C		
	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo	1-mo	3-mo	6-mo
Raw sliced pork									
Session I (2 reps)	7	8	10[a]	6	10[a]	7	8	13[c]	18[c]
Session II (2 reps)	10[a]	7	8	9[a]	13[c]	14[c]	7	15[c]	17[c]
Combined (4 reps)	17[a]/34	15/32	18[a]/36	15[a]/32	23[c]/32	21[b]/36	15/32	28[c]/32	35[c]/36
Cooked sliced pork									
Session I (2 reps)	10[b]	8	5	8	12[c]	17[c]	11[b]	16[c]	16[c]
Session II (2 reps)	8	10[a]	11[a]	8	12[c]	13[c]	8	12[c]	17[c]
Combined (4 reps)	18[b]/32	18[a]/32	16/36	16[a]/32	24[c]/32	30[c]/36	19[b]/32	28[c]/32	33[c]/34

[a]Significantly different - 5% level.

[b]Significantly different - 1% level.

[c]Significantly different - 0.1% level

Table 13. Mean scores and differences, and significance of differences between paired scores for freeze-dried raw pork slices after 6 months of storage[a]

Temperature Effect	Tender-ness	Mealiness	Fibrous-ness	Wetness	Darkness	Off-flavor	Desir-ability
	Sensory Parameter						
28°C	1.78	0.83	2.11	0.83	2.00	0.83	1.22
-40°C	1.78	0.83	1.78	1.00	1.61	1.17	1.33
Difference	0	0	+0.33	-0.17	+0.39	-0.34	-0.11
Significance[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
38°C	1.05	0.76	2.67	0.81	2.19	1.00	0.62
-40°C	2.10	0.90	1.86	1.48	0.95	0.62	1.90
Difference	-1.05	0.14	+0.81	-0.67	+1.24	+0.38	-1.28
Significance	≠	N.S.	≠	≠	*	N.S.	*
48°C	0.80	0.83	3.29	0.31	3.06	1.97	0.20
-40°C	2.40	0.94	1.86	1.71	1.09	0.23	2.17
Difference	-1.60	-0.11	+1.43	-1.40	+2.57	+1.74	-1.97
Significance	*	N.S.	*	*	*	*	*

[a] Rehydrated cooked pork scored by nine panelists in two sessions with two replicates per session. 0 = none, 4 = extreme.

[b] Significance of differences between temperatures tested by t test for paired observations.

* Significant at 1% level

≠ Significant (1%) overall, but only significant in one of two sessions treated separately.

NOTE: N.S. means non significant.

Table 14. Mean scores and differences, and significance of differences between paired scores for freeze-dried cooked pork slices after 6 months of storage[a]

Temperature Effect	Sensory Parameter: Tenderness	Mealiness	Fibrousness	Wetness	Darkness	Off-flavor	Desirability
28°C	1.53	1.27	2.13	1.20	1.93	1.13	1.13
-40°C	1.87	1.20	1.80	1.47	1.47	0.87	1.53
Difference	-0.34	+0.07	+0.33	0.27	+0.46	+0.26	-0.40
Significance[b]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
38°C	1.87	1.60	1.67	1.33	2.10	1.07	1.23
-40°C	2.13	1.37	2.10	1.37	1.17	0.73	1.53
Difference	-0.26	+0.23	-0.43	-0.04	+0.93	+0.34	-0.30
Significance	N.S.	N.S.	N.S.	N.S.	≠	N.S.	N.S.
48°C	1.06	0.97	2.88	0.97	3.30	1.00	0.64
-40°C	2.06	1.39	1.52	1.64	0.88	0.36	1.82
Difference	-1.00	-0.42	+1.36	-0.67	+2.42	+0.64	-1.18
Significance	≠	≠	*	*	*	*	*

[a] Rehydrated cooked pork scored by nine panelists in two sessions with two replicates per session. 0 = *none*, 4 = *extreme*.

[b] Significance of differences between temperatures tested by t test for paired observations.

* Significant at 1% level

≠ Significant (1%) overall, but only significant in one of two sessions treated separately.

NOTE: N.S. means non significant.

Table 15. Effect of phosphate-salt treatment on moisture pick-up, cooked yield, and rehydration

Treatment	Effect	Lot			
Soak, 3 hr, 3°C		1 (water)		2 (3% Kena, 4% NaCl)	
	% pick-up	3.5		11.4	
Cook, chill	% yield*	74.1		86.8	
Soak, 3 hr, 3°C		1a (air)	1b (Kena-NaCl)	2a (air)	2b (Kena-NaCl)
	% pick-up	—	5.2	—	5.2
Freeze, -23°C air	% moisture	67.8	69.1	75.0	75.2
Freeze-dry	% moisture	0.14	0.27	0.18	0.22
Rehydrate	% moisture	64.4	67.3	67.0	68.5
	Ratio, rehydrated/ freeze-dry weight	2.81	3.05	3.02	3.18
Press out, 500 kg	% moisture pressed out	26.0	20.8	20.5	21.0

*Yield based on raw, unsoaked weight.

Table 16. Mineral content of freeze-dried products

Soaking Treatment	Lot 1a	Lot 1b	Lot 2a	Lot 2b
	Water-Air	Water-Salts	Salts-Air	Salts-Salts
% Ash	3.63	6.58	6.06	10.62
% Chloride (Cl)	0.09	0.66	1.03	1.04
% Phosphorus	0.62	0.81	0.92	1.16